STUDIES ON KENKEY -- A FOOD PRODUCT MADE FROM CORN IN GHANA

by

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INTRODUCTION

World Food Situation

One of the major problems of our times is the provision of food, in quality and quantity, for the health and normal development of man. The dimensions of the problem are global.

The geographic center of gravity of the world's food problem is in South East Asia, where large populations with low incomes, poor diets and relatively small potentials for increased food production prevail (22, 45). In 1963, the Food and Agriculture Organization of the United Nations (34), reported that 60% of the people in developing areas were suffering from malnourishment, defined as an improper nutritional balance in the diet. The make-up of diet in terms of its content of different foods varies widely from region to region; even so, it has been estimated (22, 34, 56) that about 70 to 81% of the calories consumed in the developing countries are supplied by cereals, starchy roots, and sugar. Concentrations this high are cause for concern, because the foods in this class are not noted for their health protecting qualities, and when too much reliance is placed on them, deficiencies in vitamins and proteins are usually major problems (47, 71). Deficient supplies of proteins are a vital concern because protein nutrition is very important to young children and has direct and indirect effects on adult health (30, 71). Evidence is clear on the effects of protein malnutrition on the predisposition of adults and children to infection, on reduced stature and retarded psychomotor development in adults malnourished in younger years, on reduced birth weight, on impoverished lactants, and on differences in recovery from surgery, trauma, and other pathological states (36). The Food

and Nutrition Board, National Academy of Science - National Research Council, of the United States (64) reported that the segment of the population most severely damaged by malnutrition in nearly all the developing countries is in the range from weaning to 5 years. In most areas up to 50% of the children fail to survive to school age directly or indirectly as a result of poor nutrition. Among those that do survive, permanent stunting is equivalent to two or three years of their most rapid growth, and the central nervous system also may be irreversibly damaged in a degree comparable to the suppression of this growth. The task of increasing food supplies to provide adequate diet for the entire human race assumes greater dimensions when viewed against the background of the rates of annual population growth. Brown (18) gives a forceful and succinct summary of the world's population and its urgency: "At the time of Christ, world population was estimated to have numbered about 250 million. This number slowly expanded and by 1600, it had doubled, reaching 500 million. During this 16 - century interval the rate of increase ranged between two to five percent per century. By 1900 the annual rate of increase was merely one per cent. As of 1960, it was estimated at about two percent and expected to be well above this figure for the rest of the century." With the world's population in the past five years growing twice as fast, at 2% a year, as the food output, the nature of man's struggle against hunger is surely evident. But this struggle is beset with political, social, economic, and technical obstacles. The need for changes in agricultural practices, food processing and technology, and in food habits to provide enough food of the right kind and at a price within the purchasing power of the consumer is very imminent (22, 30, 33, 46). The Food and Agriculture Organization (33)

estimated that about 5 to 10% of the world's food grain is lost; 5% representing about 50 million tons is lost because of faulty storage, most of it in countries which are short of food and can least afford the loss. These losses alone would be sufficient to feed 400 million extra people at a per capita consumption rate of about 120 kilograms. A successful program for improving food quantity and nutrition in general will, no doubt, reduce mortality among children, but will temporarily accentuate the population problem. However, at a later stage of national development the rate of population growth generally decreases because of a lowering of the birth rate (46, 78).

Humanitarian considerations demand that children now living should be helped to obtain the type of food they need. It is not enough to merely mention these thoughts. To pursue them in a significant and meaningful way is to give not only comfort and encouragement but also strength to those already engaged in and dedicated to alleviating this problem. To this end the studies on kenkey have been undertaken.

Kenkey and its Traditional Processing Techniques

To permit better understanding of the significance of these studies, an attempt has been made to describe kenkey in terms of its processing techniques because no concise definition of the product could be given without loss of details by the reader who is unfamiliar with this type of food. Essentially, kenkey could be considered as a fermented mush made from white corn meal. In its first stage of processing, naturally dried corn kernels in wholesome condition are washed to get rid of extraneous materials and then

soaked in water. After one or two days any remaining free water is discarded and the grain is ground into a partially bolted meal. After grinding the meal is mixed with enough water to form a stiff dough. It is then covered and allowed to ferment for two to three days. The dough is then divided into two parts one of which is cooked, usually in round-bottomed iron pots. In the cooking process, water flavored to taste with salt is brought to boil in the iron pots; the dough is molded manually into small balls which are dropped into the boiling water. The addition of salt may be omitted, depending on the type of kenkey that is being processed. Soon after the dough balls are dropped into the boiling water, a specially designed wooden laddle is used to vigorously stir and mash the dough in order to avoid lumping. More water is added when necessary and the shearing and stirring continued until a desired consistency is attained. When the dough is about half-cooked, it becomes what is known as 'aflatta'. The aflatta is combined with the uncooked portion and thoroughly mixed. The product is then divided into balls of about a pound or so, each wrapped in clean wet maize husks or wilted plantain leaves and boiled for about two to several hours at the end of which the balls are ready to eat. A diagrammatic representation of the methods of kenkey processing is shown in Fig. 1.

Varieties of Kenkey

There are several varieties of kenkey (83). These varieties are made by the same basic processing techniques and procedures as outlined in Fig. 1. However, the differences depend to a large extent on the degree to which the basic steps (viz., milling, fermentation, heat treatment and wrapping) are accomplished. The addition or omission of salt and the kind of wrapping

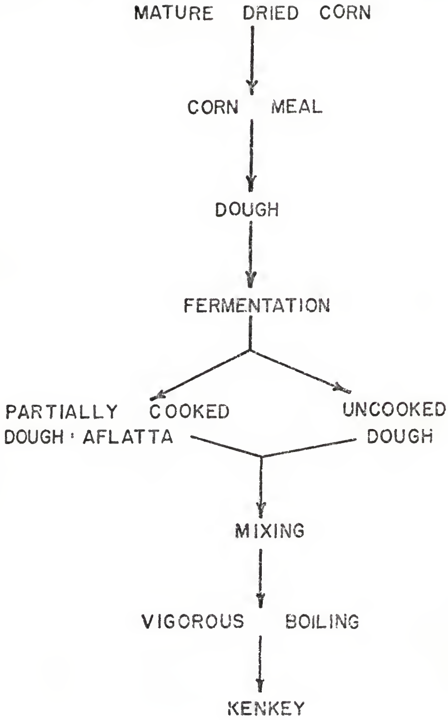

Fig. 1. A schematic flow for kenkey processing.

materials exert pronounced effects on the flavor of the final product. Most varieties of kenkey have been named after certain tribes and geographical regions in Ghana. The Ga kenkey (komi), for example, predominates in the Eastern region; the Fanti kenkey (Ntaw dekon) in the Central region; polished kenkey (nsihu) in the Western region, Ewe kenkey (Kokui) in the Volta region and Asante kenkey in the Ashanti and Brong Ahafo regions. A map of Ghana showing these regional distributions is given in Fig. 2. One meets with all these varieties in any one region but marketing conditions and tribal preferences dictate the preponderance of any one variety.

The Ga kenkey is the type described under Fig. 1. In this variety, salt is always added and the combined uncooked dough and aflatta is wrapped in corn husks and cooked without further resting period or fermentation.

In making the Fanti kenkey, the combined uncooked dough and aflatta is rested to ferment for some time, before the cut pieces are wrapped in plantain leaves. No salt is added.

When corn is dry milled for polished kenkey, the bran and the germ are almost completely removed. Nsihu is thus made chiefly from the endosperm of the corn kernel. Corn husks or plantain leaves may be used for wrapping.

The Ewe kenkey is similar to the Ga variety in that the balls are wrapped in corn husks only. The differences are that salt is not added, and the combined dough and aflatta is rested for up to six or more hours to referment before it is cooked.

To make a sweet kenkey variety, sugar or cooked mashed sweet potatoes (Ipomea spp.) is added to the combined dough and aflatta to impart sweetness.

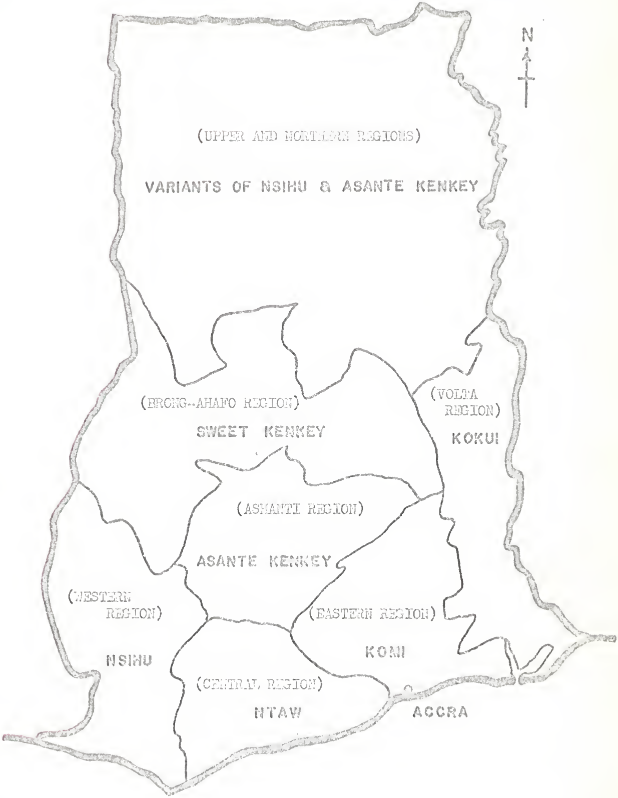

Fig. 2. Map of the Republic of Ghana, showing regional boundaries and the distribution of kenkey varieties.

The Role of Kenkey in the Ghanaian Diet

It has been observed (5) that as a food item, kenkey is second in importance after fresh cassava (Manihot utilissima) and rice (Oryza sativa) in the group of staples in the Ghanaian capital, Accra. In the western and coastal regions kenkey falls to third place after plantain (Musa spp.) and to a lower but significant place in the upper and northern regions even though corn is naturally scarce there. Generally kenkey is eaten with a stew, fish or meat with sauce, gravy or a variety of soup preparations. While the descriptions of these foods are outside the scope of this present work, a brief mention of their nature is necessary to throw some light on how kenkey is served. The stews range from a clear seasoned broth to a mixture of several ingredients such as pepper (Capsicum spp.), egg plant (Solanium melongera), tomatoes, onions, okra (Hibiscus esculentus) and/or other green vegetables, and fish or meat cooked in palm oil (Elaesis guineensis) or coconut oil. Since kenkey is predominantly carbohydrate, it is the stews that nutritionally provide the bulk of fats, proteins, vitamins and minerals in the diet. The proportion of kenkey in the diet depends, to some extent, on the income of the family or individual. Because the product is cheap and has satisfying flavor and gastronomic appeal, it tends to rank high in the dietary of families and individuals in the lower socio-economic status. The preponderance of maize in a diet is a cause for concern from the standpoint of growth and healthy development, because predominantly maize diets have been associated with high incidence of Kwashiorkor (47, 84). Kwashiorkor is a disease caused by inadequate intake of good quality protein, and is common in Latin America, Africa, and the Near and Far East. It occurs among infants and children, usually between the ages of 1 and 4 years, and most frequently

in infants following weaning when they are put on diets of cereal products that are low in quality and quantity of protein. Kwashiorkor is characterized by retarded growth, mental apathy, edema, changes in texture and pigmentation of the hair and skin, anemia, anorexia, and diarrhea. Scrimshaw and co-workers (71) in studies in Guatemala have found that young children suffering from protein malnutrition are more susceptible to infections and diarrheal disease than well-nourished children.

The State of Dry Corn Milling in Ghana

The present status of dry corn milling technology in Ghana is very simple. Many small towns have their own corn mills in which simple petrol engines attached to small attrition mills are used (51). In the rural areas, the major method is to pound the grain in a fairly large wooden mortar with a pestle made of heavy wood. The result of the first stage in the pounding, where each grain is broken into several portions is known as 'cracked corn'. In the northern and upper regions of the country, the grinding of corn in mortars is done mostly by women. Specially shaped mortars and pestles have been designed for this purpose, and by their use, very fine white flour can be produced. In some areas grain is soaked first to soften it, and may be pounded more than once in order to produce a finer flour. In the grasslands and woodlands regions, grain is also ground between two stones and coarse flour from the mortar may be ground further between millstones to produce a finer granulation. Although the processing techniques fall broadly into only a few categories, demonstrable variations in product result, accounting in part for the large differences in color, texture, and flavor observed in the different varieties of kenkey.

Objectives of the Study

From the foregoing discussions, the great need for 1) a study of the latent scientific principles involved in kenkey processing and 2) the need to determine the more important factors effecting the quality of kenkey cannot be ignored. Indeed, the hope of stimulating interest in the underlying but undeveloped science and technology of traditional food processes in Ghana, and the prospects of effecting nutritional enrichment programs in future work prompted the present studies on kenkey. These are the primary objectives.

REVIEW OF LITERATURE

Corn Production in Ghana

Corn is Ghana's most important staple cereal, being grown mainly in the coastal thicket and savanna and forest zones (39). Other important cereals are millet (Pennisetum typhoideum), guinea corn, known as grain sorghum in the United States (Sorghum vulgare), and rice (Oryza sativa). With increasing urbanization, corn has become an important cash crop. Its cultivation in some places has become noticeably commercialized. Present yields on Ghana's cereal farms are quite low. In 1964 (40), it was estimated that farmers produced between 500 and 800 lbs. of maize per acre when growing traditional varieties. Available improved types, in the same year, yielded about 1,200 lbs. an acre. If the seeds were dressed and sown at densities recommended by the Crop Research Unit of the Ghana Academy of Sciences, further increases in yield could be readily obtained. Yields up to 2,500 lbs. per acre from improved varieties grown on Government Agricultural research farms have been recorded. Little corn is exported, however. Several varieties of

corn occur in Ghana (51), the main differences being minor ones, such as the color of the grain, which is generally yellow, white or reddish. White dent corn has become increasingly popular with farmers and in kenkey processing. Essentially it is for the dried grain that corn is grown in Ghana.

The Structure and Chemical Composition
of the Mature Corn Kernel

A comprehensive review of the available literature on the chemical composition of the mature corn kernel was made by Cannon _et al_, (20) in 1952. The literature covered in this review included all references from British Abstracts: 1880 through 1913, underheadings, corn, _Zea mays_, and maize. Chemical Abstracts, 1906 through August 1951 under the headings: corn, _Zea mays_, maize and feeding stuffs; in Experiment Station record, 1889 through 1946; in Biological Abstracts 1926 through 1947; in Bibliography of Agriculture 1922 through 1950 and Maize bibliographies for 1888 to 1916, inclusive; and 1917 to 1936, inclusive, of the Iowa Corn Research Institute. In addition bibliographies accompanying these articles were also used to obtain additional references. This extensive review indicated that the chemical composition of the mature corn kernel was relatively well known. However, it is desirable to re-evaluate these proximate analyses if new food products are to be developed.

The typical corn kernel is divided into the following parts (20):

i Hull or bran (pericarp & seed coat),

ii Tip cap,

iii Endosperm (including aleurone cell layer),

iv Embryo or Germ, as shown in Figure 3.

The distribution of the major chemical constituents and the proximate

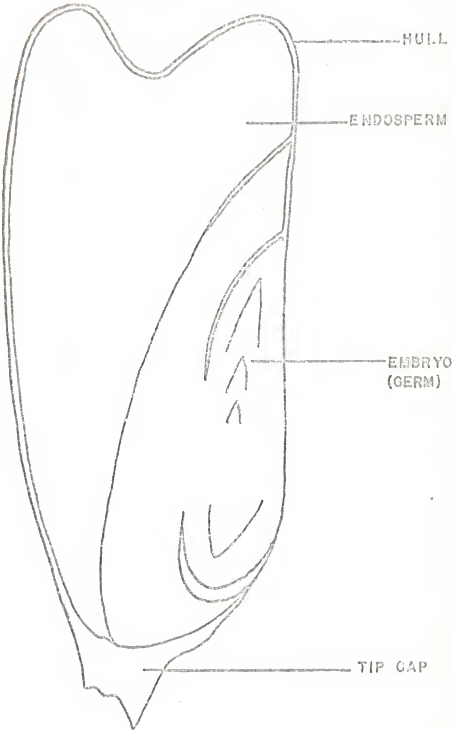

Fig. 3. A longisection of the kernel of dent corn showing the major structural components.

analysis of a typical U.S. dent corn variety are shown in Table 1. The values are expressed as percentage of total constituent, on a moisture-free basis (8, 20, 63, 74).

Table 1. Components of the kernel of a typical U.S. dent corn variety.

Structure	Weight % total	Crude protein %	Ether extract %	Ash %	Carbohydrates %
Whole kernel	100	8.3 - 10.2	3.1 - 5.7	0.9 - 5.0	79.3 - 89.1
Hull	5.0	2.0 - 2.9	1.0 - 1.1	2.4 - 3.4	6.65
Endosperm	82.0	74.3 - 77.7	15.1 -16.1	17.0 -22.4	87.11
Germ	12.0	19.2 - 22.9	82.2 -83.0	73.0 -79.6	4.71
Tip cap	1.0	0.6 - 0.87	0.5 - 0.7	0.8 - 1.2	1.56

The chemical composition of the dry matter of corn in common with that of other foods of plant origin varies over rather wide limits, as it is influenced by 1) genetic composition, 2) soil, and 3) climatic factors (8). Variations are encountered in the relative amounts of protein, lipids, carbohydrates, pigments, vitamins, and ash; the nature of the mineral elements present is also subject to wide variation.

The Protein of Corn

From the nutritive standpoint, the chemical composition of corn protein is of great importance. Four simple types of proteins have been reported in the corn kernel (65), namely: the glutelins, albumins, globulins and prolamines. These have been classified on the basis of their solubility; thus

the albumins are soluble in water, the globulins in saline solutions, the prolamines in alcohol and the glutelins in alkaline solutions. Also some nucleoproteins which are classified among the conjugated proteins are found in the germ (20). The presence of small quantities of free amino acids in the corn kernel has been reported by Zeleny and Coleman (87). While studying the acidity of corn, these workers found that 11.7 mg of potassium hydroxide were required to neutralize the free amino-acids in 10 grams of kernels, on a dry basis. Osborne and Mendel (65) studied the distribution of the different types of protein in the endosperm and in the germ, as well as the amounts in the whole kernel. These studies have been reviewed by Cannon _et al._ (20). From a nutritive standpoint corn proteins, like other cereal proteins, are not as high in biological value as those of certain of the legumes (37, 65, 70). Zein, the chief protein in corn is lacking in lysine and low in tryptophan and methionine (11). Zein will not even maintain life in the rat, but when supplemented with these amino acids and fed at a sufficiently high level, it will maintain the nitrogen equilibrium of the rat and serve as the source of protein in the diet.

Corn Lipids

The chemical composition of corn oil has been investigated by a number of workers (6, 16, 20, 41, 44, 49, 81). The lipids are located largely in the germ and consist of fatty oils, phosphatides such as lecithin, and unsaponifiable materials like the sterol isomers known as sitosterol. The fatty acids of corn which have been reported quantitatively include stearic, palmitic, oleic, linoleic, linolic, ricinoleic, arachidic, hypogaeic, formic, acetic, caproic, caprylic, and capric (20).

The Carbohydrates of Corn

The cereals are predominantly carbohydrate foods. The principal polysaccharide present in the corn kernel is starch, but small quantities of dextrins (0.32%) are also usually found (20, 25, 28, 56, 75, 80). Corn starch occurs in granules generally comprised of a mixture of two types of molecules, both of which are polymers of glucose. One type, amylose or A-fraction, is believed to be a long, unbranched chain. The chain consists of glucose units joined in the majority of cases through glucosidic 1,4 linkages (48). The other type, amylopectin or B-fraction has been shown on the basis of methylation studies to be a branched-chain polysaccharide, one terminal glucose occurring for every 24 to 30 glucose residues. The glucose residue which is situated at each point of branching is attached to carbon -4 or more rarely to carbon -6. The former branching site has long been established. Isolation of the alpha, 1-6 disaccharide, isomaltose, from the products of incomplete hydrolysis of amylopectin proved the presence of the other type of branch points (9).

The Mineral Constituents of Corn

Ash is the mineral residue left when a sample of ground corn kernel is heated in a silica dish under prescribed conditions until all of the organic material is destroyed, but without causing the volatilization of non-combustible constituents (8). In the ash of corn, potassium, phosphorus and magnesium predominate, followed by sulfur, chlorine, calcium and sodium (20). A considerable part of the phosphorus is in the form of phytin, the calcium or magnesium salt of phytic acid (inositol hexaphosphoric acid) and there is considerable question as to the availability of phosphorus in this form (8).

Enzymes in the Corn Kernel

In 1952, the early literature on the subject was reviewed by Cannon _et al_. (20). Among the enzymes reported were 1) an oxidizing enzyme similar to the peroxidase of barley, 2) cytochrome oxidase, 3) phosphorylase, 4) both alpha- and beta-amylase and 5) negligible amounts of pyrogalloloxidase. Glutamic acid decarboxylase has since been reported by Linko (57). These and doubtless other enzymes catalyse the changes that occur during growth, ripening, storage, and processing. Zeleny (86) suggested that the lipases are responsible for the increase in fat acidity which occurs when corn or its products are stored at moisture levels which are too low to permit mold and bacterial growth.

The cereal alpha-amylases are among the earliest known enzymes but less is known today of the mechanism of reaction of alpha-amylases than of that of many other enzymes (9, 10, 38, 50). It is believed, however, that alpha-amylase acts as follows:

i. The primary function is dextrinization and in consequence, liquefaction or destruction of viscosity. The amylose and amylopectin molecules are broken down by fission of alpha-1,4-glucosidic linkages into alpha-dextrins of small molecular weight.

ii. Saccharification follows dextrinization but overlaps it. This involves the fission of alpha-1, 4-linkages which have escaped previously. While alpha-maltose is the principal product, it is not surprising that glucose too is formed at this stage concurrently with maltose.

iii. The degree of increased saccharification is not directly proportional to increase in alpha-amylase concentration, the behavior following the law of diminishing returns.

The specific action of beta-amylase has been reported as follows (4, 9, 10, 50); only alpha-1,4-glucosidic linkages are attached. Fission commences with the second alpha-1,4-glucosidic bond from the non-reducing end of a chain (or branch). When this has been broken and a maltose molecule formed and removed, the second link in the remainder of the chain is in turn attacked. If no branching occurs in the molecular chain, hydrolysis continues to completion, maltose being the sole product unless the presence of an odd number of glucose residues results in the last three of them, constituting maltotriose, remaining unattacked. Branched molecules, that is, chains of glucopyranose residues, linked by alpha-1,4-glucosidic bonds, but also branched or laminated, whether by alpha-1,6-glucosidic linkages or otherwise, are completely hydrolysed. The process commences as with amylose at the non-reducing ends but stops at the near approach to a point of branching.

The Microflora of the Corn Kernel

Literally hundreds of thousands of different kinds of micro-organisms exist in nature and each kind is capable of fermentative changes (7). The microflora of cereal grains and cereal products is made up of a wide variety of fungi and bacteria including actinomycetes (72). These micro-organisms are the same as those found in soil and air, and on or in living or dead plants and animals. Their kind and abundance depends on such factors as the climate under which the grains are produced, the conditions of storage and portions of the grains of which the products are composed. Bottomley <u>et al</u>. (12) demonstrated that in stored yellow dent corn, mold count and fat acidity of the aerated samples generally increased as the moisture content increased

up to 31.9%. It was observed that at any given relative humidity or moisture content, the extent of these changes increased with the duration of storage. For example, in samples stored at 19.0% moisture or 80% relative humidity, the mold count increased from an initial value of between 10,000 and 14,000 per gram to over 30,000 after twelve days. The viability of corn fell from an initial value of 85% to 53% during the trial but there was little change in fat acidity and non-reducing sugar content. In contrast, in the corn at the highest moisture level (31.9% in equilibrium with 100% R.H.) the mold count increased from an initial value of 44,000 to 32,000,000,000 per gram after twelve days storage; the viability fell to zero, the fat acidity increased approximately four fold and the non-reducing sugars decreased to one-seventh of their original value. The concomittant growth of micro-organisms and increase in fat acidity with increasing moisture content has been noted in other grains besides yellow corn: in wheat by Milner _et al_. (61), and by Carter and Young (21); in soybeans by Milner and Geddes (62), in cottonseed by Christensen _et al_. (23); and in rice bran by Loeb and Mayne (58). The work of Milner _et al_. (61) is of particular interest because, among other findings, it indicated that different storage molds have different moisture requirements for growth. Among the molds inhabiting sound seeds were species of _Alternaria_, _Fusarium_ and _Helminthosporium_. Even though these species are encountered at harvest and in storage bins, none of them is able to grow at a seed moisture below 25%, so all disappear relatively rapidly from seed stored at 18% moisture. Koehler (54) has shown that the species of mold mentioned above are unable to grow in corn stored at a moisture content below 21 to 23%. Milner _et al_. (61) indicated also that the species of _Alternaria_, _Fusarium_, and _Helminthosporium_ isolated were

unable to compete with Aspergillus species even on grain at high moisture content. The majority of molds isolated from germ-damaged seed make up the dominant flora which proliferate at moistures between 14.5 and 20%. For example, Aspergillus glaucus is able to grow on seeds at below 16% moisture content; A. candidus at 17% and A. flavus and certain Pericillium species from 18 to 20% seed moistures. In studies of the effect of innoculation on seed viability at 18% moisture, it was found that the seed viability was lowered at 20% moisture and that Aspergillus candidus and A. ochraceus lowered it more than did A. glaucus. Observed chemical changes, such as lipolysis and sugar hydrolysis, were more rapid in samples stored at 18% moisture than in those stored at 12.1% moisture. It has been shown by some independent workers that molds and bacteria can produce the enzyme, lipase (29, 59, 76). From their studies on Philippine rice mill products and the preservation of rice bran, West and Cruz (82) concluded that under the action of moisture mold lipase will hydrolyse the glycerides of the oil in the grain to form free fatty acids.

Kenkey Fermentations

The nature of kenkey fermentation has not been established with certainty. However, the pronounced alcoholic and vinegary flavor of the fermented dough and of the final product, kenkey, suggests that the process of fermentation that occurs is alcoholic in nature. Alcoholic fermentation has been defined generally (43, 66, 77) as the enzymatic conversion of carbohydrates into alcohol and carbon dioxide. Although alcoholic fermentation was one of the earliest of human discoveries, it is only within about the last century and a half that scientific interest has centered upon elucidating the actual

chemical reactions involved in the process (17). The technological importance of alcoholic fermentation is highest in the brewing, distilling and baking industries (13, 17). Through the years, the cereal grains have been used either singly or severally and with yeast to provide the required substrates and enzymes in baking and brewing. It is now clear that two independent groups of enzymes are involved in such fermentations. One of the groups consists of the invertase, maltase, and zymase systems of yeast. The other group is the amylases of the cereal grains and their products (17, 38). In its simplest form, the chemistry of fermentation relates to the chemical reactions that occur when sugars (carbohydrates) are transformed by the action of yeast to carbon dioxide gas and alcohol according to the general formula (17):

$$\underset{\text{glucose}}{C_6H_{12}O_6} \longrightarrow \underset{\text{carbon dioxide}}{2\,CO_2} + \underset{\text{alcohol}}{2\,C_2H_5OH}$$

The fermentation would be of the type designated the Embden-Meyerhof-Parnas scheme (77), in which both ethanol and acetic acid are formed from glucose according to the following reactions:

$$\begin{tikzcd} \underset{\text{glucose}}{C_6H_{12}O_6} \arrow[r] & \underset{\text{Acetaldehyde}}{CH_3CHO} \arrow[r, "H_2O"] \arrow[d, "4H"] & \underset{\text{Ethanol}}{C_2H_5OH} + \underset{\text{Acetic acid}}{CH_3COOH} \\ & \underset{\text{Ethanol}}{CH_3CH_2OH} & \end{tikzcd}$$

It is possible that these reactions would occur concurrently with "Neuberg's third form of fermentation" (15) expressed as:

$$\underset{\text{Hexose}}{2C_6H_{12}O_6} \xrightarrow{H_2O} \underset{\text{Ethanol}}{C_2H_5OH} + \underset{\text{Acetic acid}}{CH_3COOH} + \underset{\text{Glycerol}}{2CH_2OHCHOHCH_2OH} + \underset{\text{Carbon dioxide}}{CO_2}$$

Theoretically, these reactions proceed quantitatively when pure sugars and

yeast are involved and give only alcohol and carbon dioxide. However, the cereal grains contain only a small proportion of the simple six carbon sugars and so a relatively larger proportion of polysaccharide need be converted into these sugars if rapid fermentation is to be sustained. This is accomplished in part by the action of the enzymes, diastase (amylase) and invertase.

Quality Factors of Kenkey

Quality is a variable that may be good or bad, high or low (55). Quality is not necessarily that which is excellent or highly desirable. It must be recognized that a particular factor of quality or a particular level of quality may be of importance in some instances and not as important or of no importance at all in others. Kramer (55) has indicated that, in every case, the scale of evaluation of quality must be geared to the purchaser of the product. Kramer emphasized, quoting John Hammond of Cambridge University, England, that "quality is that which the public likes best." He indicated further with a quotation from Cheftel that "wholesomeness and nutritional value are but two of the total characteristics contributing to the 'quality' of a particular food." The importance of nutritive value of food as a quality aspect has been recognized by other workers and organizations (36, 63, 64, 71). Analytical data can be used as the basis for comparing kinds and amounts of nutrients in different foods. On the basis of these thoughts, the quality of kenkey may be divided into two major categories: chemical and physical. In the present studies, the chemical quality factors are related to the nutritive value of kenkey. This evaluation is necessary, firstly, because of the widespread use of the product in the

Ghanaian diet, and secondly, because of the limiting levels of nutrients in the raw material - corn. The factors demanding first attention are the relative proportions of proteins, fats, carbohydrates, minerals, moisture and calories. In quality evaluations, it is also extremely important for the consumer to know that the food, apart from nutritive value, cannot cause him any ill effects. But since the consumer cannot judge for himself if any toxic or other harmful ingredients are present in commercially processed foods, it is necessary to establish rather elaborate controls, both at government and industry levels to protect the consumer against unwholesome foods. The control of quality in kenkey production is one of the ultimate aims of the present studies. The physical evaluation of kenkey has been approached from the standpoint of the human senses of perception, i.e., by organoleptic tests. Characteristics of primary importance are color, shape, size, grain, texture and flavor, including both taste and aroma.

MATERIALS AND METHODS

White dent corn variety Pride of Saline, obtained from the Agronomy farm of the Kansas Agricultural Experimental Station at Kansas State University, Manhattan, was used for the study. The corn was cultivated on plots on which soybeans had been grown the year previously. Ammonium nitrate fertilizer was applied once at the rate of 190 pounds per acre during cultivation. The crop was harvested with an average yield of 90 bushels per acre. The condition of the corn as raw material for food would be described as excellent with respect to freedom from molds and foreign matter. It was found on physical examination that the moisture content was 11.2% on a dry weight basis, the test weight was 52.9 lbs. per bushel and the 100 kernel

weight was 27.6 grams.

Experiment 1. Dry Milling Technique.

Preliminary tests showed that partially degermed corn meal containing minimum bran and tip cap and with particle sizes of minus 50GG mesh was best suited for the variety of kenkey under study. The dry milling process consisted of four major stages, viz: cleaning, tempering, grinding, and sifting. After thoroughly cleaning the corn by means of a Carter dockage tester, 2,500-gram portions of the grain were conditioned by raising the moisture content from 11.2% to 20% in an experimental rotating tempering device. The amount of water needed for conditioning was calculated from the following formula (69).

Let W_1 = initial weight of corn (in grams).

W_2 = final weight of corn

M_1 = initial percentage moisture content of corn

M_2 = final percentage moisture content of corn

The amount of dry matter in corn remains constant, so that

$$\frac{100 - M_1}{100}W_1 = \frac{100 - M_2}{100}W_2$$

$$W_2 = \frac{100 - M_1}{100 - M_2}W_1$$

Hence, the weight of water to add = $W_2 - W_1$ gms. Stiver (74) has listed the principal objectives of conditioning as follows:

(a) to loosen the hull or bran and at the same time toughen it, making it easier to remove in large pieces;

(b) to toughen the tip cap so that it will stay with the hull,

(c) to moisten the endosperm for milling which helps to produce maximum

grits and minimum flour.

After a holding period of 24 hours in plastic bags, the cleaned and tempered corn was ground on Ross experimental roller mills. The interrelationships of a series of grindings and siftings and the resulting products of the corn dry milling process are shown by the milling flow in Figure 4. Also, roll corrugations, grinding speeds and roll spacings are shown. The rolls which were all corrugated were of the "Getchell" type of $\frac{1}{4}$ inch spiral cut. The grinding action was dull-to-dull with a differential of 2.5:1. For the four successive break grinds, the roll spacings used were .050, .020, .006, and .003 inch, respectively. The corrugations of the first and second break rolls were coarser in comparison with the fine corrugations of the third and the fourth. On the first break roll, grinding was aimed at partially scrubbing off the hull from the corn kernel, loosening the germ and breaking the kernel into two or more pieces. This product was sifted for 2 minutes on a Smico laboratory sifter using 5W, 10W, 20W, and 50GG screens in that order of increasing fineness. The overs of 5W consisted of hull, tip cap and germ. These were discarded. The overs of 10W were ground on the second break roll and sifted through 10W, 20W and 50GG Smico sifters for 2 minutes. From the second break rolls, the overs of 10W which were mostly hulls were discarded. The overs of 20W, generally known as brewer's grits, obtained from previous siftings were combined, passed through the third break roll and then sifted through 20W, and 50GG screens for two minutes. The combined overs of 50W from the preceding grinds, generally known as corn cones or coarse corn meal, was passed through the fourth break roll, to produce corn meal of finer particle sizes. This finer corn meal was the product used for making kenkey and which was subjected to subsequent analyses. The

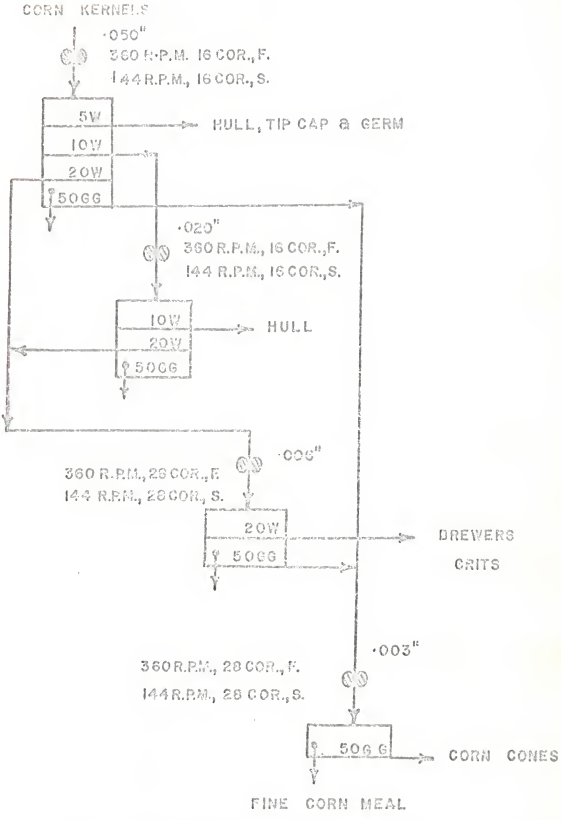

Fig. 4. A schematic flow for the dry milling of corn for kenkey processing.

percentages of all the millstreams and milled products were recorded.

Experiment 2. Dough Handling and Processing.

After a series of trials a simple formula for making kenkey was developed on the basis of existing traditional methods. The basic ingredients were corn meal, water and salt. (In kenkey processing the addition of salt is optional depending entirely on the variety of product desired). The amount of ingredients used, as expressed in grams and in percentage based on the weight of corn meal was as follows:

Ingredient	%	Grams	
Corn meal	100	400	
Water	100	400	Stage 1
Salt	0.5	2	
Water	100	400	
Flavor	0.25	1.0	Stage 2
Water	80	320	Stage 3

The procedure was divided into three stages for the convenience of description.

Stage 1: Preparation of corn meal for fermentation: Four hundred grams of corn meal were put into the bowl of a Hobart N-50 mixer, fitted with a B-flat paddle. An equal amount of water at 80°F. was added to the corn meal and the mixture blended at a low speed of 575 r.p.m. for 30 seconds, after which the ingredients were scraped from the sides of the bowl and the paddle into the center of the bowl. Mixing was continued at the same speed for one minute to obtain uniform distribution of corn meal and water. A

stiff plastic dough formed which was transferred into a fermentation pan and fermented for 72 hours inside a cabinet maintained at 85°F. and 80% relative humidity.

Stage 2: Initial heat processing of the fermented dough. After fermentation, two-thirds of the dough was mixed with 400 ml. of water to form a suspension in an aluminum cooking vessel. Two grams of salt were added and the opaque milky suspension cooked to a partially gelatinized and almost translucent mass at between 165° and 175°F. for 15 minutes on an electric stove connected to an autotransformer. During the cooking, the mixture was constantly stirred with a wooden paddle to prevent lumping and also to allow for better heat penetration. This partially cooked and gelatinized fermented corn meal dough is known as "aflatta".

Stage 3: Final heat processing of aflatta and fermented dough: The aflatta was allowed to cool to 125°F. (65°C.) and then transferred into the mixing bowl. To this was added the remaining one-third of uncooked fermented dough and 320 ml. of water mixed with 1 gram of imitation corn flavor (provided by Fries & Fries Inc.) and the whole was blended for 30 seconds at low speed. After blending, the sides of the mixing bowl and paddle were scraped clean, and mixing was continued for 2 minutes. A soft plastic dough which could be molded between moistened fingers into round or oval balls without sticking was formed. After mixing, the dough was divided into 200 gram pieces. Each scaled piece was placed on the center of a 10 by 8-in. piece of Reynold Wrap heavy-duty pure aluminum foil and rolled into a cylindrical shape. The open ends of the foil were tucked in with gentle twisting to complete a final shape which measured approximately 4 inches in length and 2.5 inches in diameter. Alternatively, the divided dough pieces were

wrapped in 4-inch diameter plastic sausage casings cut into suitable lengths (kindly provided by Swift & Co.). The wrapped doughs were placed lengthwise in a large cooking pot. The products were loosely packed to prevent distortion of shape. Boiling water was added just to cover the doughs and then boiled further for 90 minutes at about a constant temperature of 200°F. ± 10°F. Water lost by evaporation during the boiling was restored by adding a reasonable amount of boiling water at intervals. After cooking the remaining water was discarded and the product, now called "kenkey," was allowed to cool to 80°F. At this temperature the covering aluminum foil was removed and the product examined chemically and organoleptically.

Using this procedure, replicate experiments were designed to study the effect of limiting and excess levels of water and ofvarious mixing times on the quality of kenkey.

Scoring System.

In order to arrive at some useful criteria for the evaluation of the organoleptic properties of kenkey the opinion of some consumers was sought. Ten Ghanaian students currently studying in the United States were asked, independently, to describe the factors they considered important with respect to the purchasing and eating qualities of kenkey. As a result of these interviews a score card system was developed to define some of the determinants of the organoleptic properties of kenkey and to assign some kind of quantitative values to these parameters of quality. This system was used throughout the studies and is shown in Table 7. The method recognizes three major characteristics of kenkey, viz. (i) general appearance in relation to color, shape, and size, (ii) internal features, such as grain and

texture, and (iii) flavor characteristics including taste and odor. Both major and minor factors of quality have been weighted according to the method of Dawson et al. (27), and so the higher the score the more important or desirable the factor evaluated in the final product. Thus a full value, that is 5/5, is awarded for excellent quality, 4/5 for good, 3/5 for fair, 2/5 for poor and 1/5 for very poor. By excellent is implied that no improvement is needed. To be rated as good, the product must be enjoyed in eating, and arouse the desire for minor improvement only. Fair means that the product could be eaten without enthusiasm and that improvement is needed. If the product is barely edible, it is rated as poor; if inedible it is very poor. When the highest possible score was greater than 5 the actual score was multiplied by the proper factor (2 x for 10, 3x for 15, 4x for 20) to obtain the weighted value as shown in Table 7.

How the Products were Scored

Color.

Uniform and very pale yellow to creamy white..............5/5

Uniform off white, corn color.............................4/5

Others..1/5

Shape.

This may be cylindrical or round to oval depending on the type of product. The product should fill the maximum space in the container. For this experiment, a perfectly cylindrical shape would be rated 5/5, nearly cylindrical 3/5, other shapes 1/5.

Size.

The size of kenkey is generally related to its price. Prices range from 3 pence to one shilling or about 4 cents to 15 cents. On the market a 4-cent kenkey weighs about 1/2 lb.

For excellent or above average weight award...............5/5

For average (good)...4/5

For below average (fair)...................................3/5

For far below average (poor)...............................2/5

For excessive underweight (v. poor)........................1/5

Grain.

The grain is here defined as the structure formed by the particle sizes of the corn meal.

Small and uniform grain....................................5/5

Small and uniform grain with very few openings.............4/5

Irregular structure and particle size......................3/5

Tunnelled..2/5

Texture.

Texture is determined by the sense of touch. It depends on the grain, amount of water and degree of mixing.

Soft, moist, smooth and lumpless...........................5/5

Soft, moist and lumpy......................................3/5

Soft and crumbly...2/5

Dry and tough..1/5

Flavor.

This is detected by the senses of taste and smell.

Taste:

Well-balanced..5/5

Slight vinegary taste......................................4/5

Faintly sweet with very slight acid taste..................3/5

Salty..2/5

Sour...1/5

Odor:

Typical corn flavor with very mild alcoholic and vinegary odor.

Moderately pronounced......................................5/5

Slightly pronounced..4/5

Noticeable...3/5

Faint..2/5

Very pronounced and off flavor.............................1/5

Limitations of the scoring system are readily recognized because of the small number of sampling population. Attempts to increase the size of the population with persons familiar with the product failed because of lack of response. It will be realized, nevertheless, that if the system is improved it will have promising applications because it can be used by persons unfamiliar with kenkey since it offers detailed descriptions as to how the scores are made.

Experiment 3. Chemical Analyses.

Analytical experiments were designed to study the influence of dry milling, fermentation and heat treatment on the proximate composition of the mature corn kernel processed into kenkey. When whole kernels were used for various analyses they were ground in a hand operated attrition mill and all

the floury product was used without sifting. Procedures for fermentation and heat treatment were as described previously. Data obtained from the analyses were reported on the dry weight basis.

Moisture Content and Total Solids

Moisture content was determined by drying the samples for one hour at 130°C. by the A.O.A.C. method as follows: Exactly 2 gm. of sample were placed in a cooled, weighed aluminum dish, provided with a cover, and previously heated to 130°C. The uncovered sample in the dish, and the cover were dried separately for 1 hour at 130°C. Then the dish was covered while still in the oven, transferred to a desiccator, allowed to reach room temperature and weighed. The loss in weight represented moisture, and the residue was reported as total solids.

Ash Determination

Ash was determined by incinerating weighed moisture-free and powdered sample for 24 hours at 550°C. according to the A.O.A.C. (2) direct method 13.006. Exactly 4 gms. of sample were weighed into a silica crucible that had been ignited, cooled in a desiccator and weighed. The sample was ignited in a muffle furnace at 550°C. for 24 hours, then the ash was cooled in a desiccator and weighed.

Crude Fat

The crude fat or ether extract determination was based on the procedure described by the A.O.A.C. (2) method 22.003. Two grams of dried sample were wrapped in Whatman No. 4 filter paper, placed in a Goldfish extractor and

extracted for 8 hours with about 50 ml. of anhydrous ether. The extracted sample was dried for 30 minutes at 100°C., cooled in a desiccator and weighed. The difference in weight was recorded as crude fat.

Total Crude Protein

The protein content was estimated by the improved Kjeldahl method for nitrate-free samples approved by the A.O.A.C. method 2.044. A conversion factor of 6.25 was used. The Kjeldahl method was carried out in two steps; first, the sample was digested with concentrated sulfuric acid and other reagents at elevated temperatures in order to convert all the nitrogen in the sample into ammonium sulfate. In the second stage, the ammonia thus formed was distilled off into a measured quantity of standard sulfuric acid. Following the A.O.A.C. procedure, a 2-gram sample was placed in a Kjeldahl digestion flask. Approximately 0.7 gm. mercuric oxide, 15 gm. powdered potassium sulfate and 25 ml. of concentrated H_2SO_4 were added. The flask was placed on the digester rack, heated gently until frothing ceased, and boiled briskly for 45 mins. after the contents became colorless. The digested material was then cooled in the flask, diluted with 200 ml. H_2O, and again cooled to below 25°C. Twenty-five milliters of 8% sodium thiosulfate solution was added without agitation, then an equal volume of saturated sodium hydroxide solution was added. The flask was immediately connected for standard distillation with the tip of the condenser immersed in 50 ml. of 0.0989N H_2SO_4. The flask was rotated to mix the contents thoroughly and then heated until all the NH_3 had been distilled over. About 150 ml. of distillate was collected. Excess acid in the distillate was titrated with 0.0977N NaOH solution with 1% methyl red as indicator. Corrections were made for a

blank determination on the reagents alone.

The method of calculation was based on the A.A.C.C. (1) methods 46-10, and 46-11. "In protein determination, nitrogen is converted to ammonia (NH_3) which reacts with water to form ammonium hydroxide (NH_4OH). A normal solution of NH_3 contains 17.032 gm. NH_3/liter. This in turn contains 14.008 gm. N_2/liter. As a consequence, 1 ml. of 0.1N NH_4OH contains 0.0014008 gm. nitrogen. Since solution of same normality are equivalent, 1 ml. of 0.1N H_2SO_4 is equivalent to 0.0014008 gm. nitrogen or 0.798% protein (0.0014008 x 6.25).

$$\text{Nitrogen } (N_2)\% = \frac{(B - S) \times N \times 0.01401 \times 100}{\text{Weight of sample}}$$

Where B = ml. alk. back - titrated of blank

S = ml. alk. back - titrated of sample and

N = normality.

Crude Protein = Nitrogen x 6.25. "

Carbohydrate

The carbohydrate content of samples was determined by the difference between 100 and the sum of percentage values for moisture, ash, protein, and fat.

Energy Value

The method of Atwater and Snell (3) was employed to determine energy levels. This consisted of multiplying the values obtained from chemical analyses for protein, carbohydrate, and fat by factors of 4, 4, and 9 cals. per gram, respectively.

Experiment 4. Fermentation of Corn Meal for Kenkey Processing.

This experiment was designed to study the effect of various fermentation times on the pH, non-reducing sugars and gross weight of corn meal dough and organoleptic properties of kenkey. Equal weights of corn meal doughs were fermented over 0, 12, 24, 36, 48, 60 or 72 hour periods. The zero hour represented a period of no fermentation. After each period, the changes in weight, pH, and non-reducing sugars were determined. The doughs were then processed into kenkey, as in experiment 2 but omitting the added imitation corn flavor, and the products judged organoleptically using a score card system.

The pH was determined by the electrometric method of the A.O.A.C., 13.027 (2), as follows: Ten grams of sample were weighed into a clean dry erlenmeyer flask and 100 ml. of freshly boiled distilled water cooled to 25°C. were added. The flask was agitated to obtain an even suspension free from lumps, which was then digested with frequent shaking. At the end of 30 minutes the suspended particles were permitted to settle for 10 minutes. A Beckman Zeromatic pH meter standardised by buffer solutions of pH 4.00 (0.05M solution of acid potassium phthalate) and of pH 9.18 (0.01M $Na_2B_4O_7.10H_2O$), both at 25°C, was used to determine the pH of the supernatant.

The determination of non-reducing sugars followed the A.O.A.C. (2) procedure 13.029. Exactly 5.7 gm. of the powdered sample were placed in a 125 ml. erlenmeyer flask. The flask was tipped so that the sample was at one side and then the sample was wetted with 5 ml. ethanol. The flask was again tipped so that the wet flour was at upper side and then 50.0 ml. of acid buffer solution added so that the solution did not come into contact with the sample until all was added to flask. The flask was then shaken to

suspend the sample in the liquid. Immediately 2 ml. of 12% sodium tungstate solution were added and the mixture thoroughly agitated. The solution was filtered at once on a Whatman No. 4 filter paper; the first 8 to 10 drops of filtrate being discarded. Five milliliters of the extract were pipetted into an 8-inch test tube which was immediately immersed in vigorously boiling water. After 15 minutes, the test tube and its contents were cooled under running water and exactly 10 ml. of alkaline ferricyanide solution were added. Next, the test tube was reimmersed in the vigorously boiling water so that the liquid in the tube was 3 to 4 cm. below surface. The contents were poured into a 125 ml. erlenmeyer flask and the test rinsed with 25 ml. of acetic acid - salt solution which was added to the 12 ml. erlenmeyer flask. The contents of the flask were thoroughly agitated and 1 ml. of soluble starch - KI solution was added. The contents were thoroughly mixed and titrated with 0.1N sodium thiosulfate solution until the blue color completely disappeared. Milliliters of ferricyanide reduced were calculated by subtracting the ml. of thiosulfate required from the thiosulfate equivalent of the ferricyanide reagent obtained from a "blank" determination. The amount of non-reducing sugars was reported as mg. of sucrose per 10 gm. flour, determined by reference to the "0.1N Ferricyanide Maltose-Sucrose Conversion Table."

Experiment 5. Animal Feeding Trial.

The objective of this experiment was to determine the effect of kenkey on the growth of rats fed without any nutritional supplement. The subjects were 4 white male Sprague-Dawley rats of 7 weeks of age and weighing between 200 and 205 grams each at the start of the experiment. Each of the rats was weighed and randomly placed in a suspended wire cage labelled to identify the

subject. To overcome deterioration kenkey was served in dried floury form. A control diet commercially known as "Purina dog chow" and consisting of not less than 24% crude protein, 7% crude fat, 4.5% crude fiber and not more than 10% ash and 12% moisture was served. The rations were given to each rat _ad_ _lib._ in a ceramic cup. The diet was loosely packed with a spoon up to between $\frac{1}{2}$ and $\frac{1}{4}$ of the way from the top of the cup which was placed at the back corner of the cage. This placement permitted the rat to move freely without running over the cup. The stock diet was placed in a refrigerator until required. On the front end of each cage, a water bottle filled with tap water was mounted three rows up with its opening end directed to the subject. Under each cage was placed a tray flatly lined with newspaper to collect food waste, urine and stools. Food and water were checked daily and refilled. To refill the food jar the following procedure was adopted: The food from the jar was removed onto a piece of clean paper towel. Fresh ration was placed in the bottom of the jar and the removed ration placed on top of the fresh ration so that it was eaten first. It was carefully ensured that food and water were available to the rats at all times for satisfactory results. The newspaper was kept out of the reach of the rats so that they could not eat it. Three times each week, the rats were weighed separately. Absolute weights were recorded from which cumulative weight gains were calculated and plotted on a graph with weight gain in grams as ordinate and time in days along the abscissa. To make the experimental conditions as uniform as possible, the daily care and weighings were scheduled at the same hour. Once each week, the ration cups, water bottles and the trays under the cages were washed and sanitized. The rats were killed after 14 days.

RESULTS AND DISCUSSION

Dry Milling

The relative proportions of millstreams and losses during the dry milling of white dent corn for kenkey processing are shown in Table 2. The relationship of millstreams to final milled products are shown in Table 3. Data presented in Tables 2 and 3 are expressed as percentages on weight of corn prior to tempering and are averages of five replicate determinations.

Table 2. Percentage in millstreams of white dent corn dry-milled for kenkey processing.

Millstreams	1st Break %	2nd Break %	3rd Break %	4th Break %
Overs 5W	8.7	0	0	0
" 10W	40.0	6.0	Trace	0
" 20W	37.2	21.5	5.7	Trace
" 50GG	10.1	11.0	45.8	27.1
Thrus 50GG	3.7	1.3	7.1	39.3
Total recovery	99.7	39.8	58.6	65.4
Loss	0.3	0.2	0.1	0.5

The technique of grinding the corn was to produce as much grits and cones as possible and less floury or finer material at the initial stages. In later stages the principle was reversed so that fewer grits and cones were produced in comparison with the large amount of finer products as shown by the data in Table 2. Milling losses included evaporative moisture loss, dust and other material losses during a series of grinding, sifting, and

weighing. It would be observed from Table 3 that fine corn meal, the final milled product used for making kenkey amounted to 51.4% of the millstream. By regrinding of brewers grits and corn cones the quantity of fine corn meal was increased to around 80%.

Table 3. Relation between milled products and millstreams of corn dry-milled for kenkey.

Milled product	Millstream	Total %
Hull, tip cap and germ	Overs 5W	8.7
Hull, without endosperm	" 10W	6.0
Brewers grits	" 20W	5.7
Corn cones (coarse meal)	" 50GG	27.1
Fine corn meal	Thrus 50GG	51.4
Losses	Grinding, sifting, etc.	1.1

Effect of Mixing on the Texture of Kenkey

During the heat processing of dough into aflatta, mixing was found to have an important effect on the consistency, grain and texture of the final product. On boiling, the dough gelatinized and formed a coagulated mass. Because heat penetration was not uniform throughout the entire mass, pockets of lumps initially formed at places where the temperature was higher and these were generally closest to the cooking vessel. In order to obtain a satisfactory product, vigorous mixing was required not only to break down the lumps but also to facilitate better and more uniform distribution of heat. If either the dough or aflatta was undermixed, the resulting kenkey

showed irregular granulation and texture. Such characteristics are undesirable. When lumps were allowed to form freely, longer mixing time and higher speed were needed to partially overcome the effect. In a lump-free dough, overmixing did not give any demonstrable results.

Effect of Water

Water showed its effect on the organoleptic properties of kenkey at two distinct phases of processing. The first was during the preparation of corn meal dough for fermentation. Excessive levels of water in the formula led to the formation of runny doughs. Such doughs were difficult to handle and required longer fermentation period. It would seem then that at such water levels, the concentration of fermentative enzymes was decreased to the extent of possibly slowing down the rate of fermentation reactions.

When water was limiting, the rate of fermentation was slowed down to a degree comparable to that produced by an excessive amount of water.

The other phase of processing at which water showed a critical effect on kenkey was during the heat treatment of fermented dough to convert it into aflatta. Addition of 50% excess water to the formula described in experiment 2, produced a light and flowy aflatta which could hardly be wrapped without dripping. When this dough was further boiled with water, the resulting product or kenkey was found to be extremely soft, tunnelled and with poor, distorted shape. Most of the dough escaped from the wrapping material before it could gelatinize. On cooling the product congealed somewhat but with little effect on the tunnels and distorted shape.

When the water content was less than 50%, the resulting aflatta was stiff and could easily be molded and wrapped. On boiling, a firm and shapely

product was formed. It appeared from the results that the amount of water used for boiling the dough after it had been wrapped had little or no effect on the consistency of the final product. It was observed however that if boiling water was used, instead of cold water, to start the final cooking of the dough after it had been wrapped, the amount of leaching was reduced. This is significant since excessive leaching of dough into the boiling water would lead to loss of nutrients.

Effect of Processing

With the exception of the carbohydrate level, the various methods employed in processing kenkey from corn kernel appeared generally to decrease the nutritive value of this product. Values of proximate analyses for fine corn meal, fermented dough, and kenkey which are products of three major stages of processing, viz., milling, fermentation, and heat treatment, have been presented in Table 4 along with those of unprocessed corn kernel for comparison.

Table 4. Influence of kenkey processing on the proximate composition of the mature corn kernel.

Nutrients	Stage of processing*			
	0	1	2	3
	Whole corn	Corn meal	Fermented dough	Kenkey
Moisture %	11.2	14.3	48.2	59.1
Total Solids %	88.8	85.7	51.8	40.9
Ash %	1.7	0.6	0.4	0.5
Crude protein %	10.9	9.5	8.2	6.1
Crude fat %	4.5	3.4	4.2	2.7
Carbohydrate %	82.9	86.5	87.2	90.8
Energy, cal/100 gm.	415.7	424.6	419.0	410.9

* 0 represents no processing

1 " dry milling

2 " fermentation (72 hours)

3 " heat treatment i.e. boiling at high temperature

Values expressed on dry weight basis.

The magnitude of the observed changes are shown in Table 5.

Table 5. Changes in proximate composition during the processing of mature corn kernel into kenkey.

Nutrients	Stage of processing		
	Milling	Fermentation	Heat treatment
Total solids %	− 2.8	−41.6	−53.9
Ash %	−64.7	−96.3	−69.1
Crude protein %	−12.8	−24.8	−44.0
Crude fat %	−24.4	− 6.6	−40.0
Carbohydrate %	+ 4.3	+ 5.2	+ 9.5
Energy, cal/100 gm.	+ 2.2	+ 0.8	− 1.2

Values are expressed as percentage of respective nutrients present in the mature corn kernel.

It would be seen from Table 5 and Fig. 5 that total solids decreased by 2.8% after milling, by 41.6% after fermentation and by 53.9% after the final heat treatment. These changes could be explained with reference to water that was added directly to the corn kernel or its products during processing, as in tempering and in dough make-up stages. As a diluent any added water would decrease the amount of total solids per unit weight. With heat treatment an additional factor was introduced to account for the higher losses. When fermented dough was boiled in water at temperatures ranging from 165°F. to 210°F., some gelatinization occurred, which increased the water retention capacity. Increases in water content resulted in decreased values for total solids.

In corn, as in most cereals, the mineral elements determined as ash, are concentrated in the germ, hulls, and tip cap. In a typical U.S. dent corn

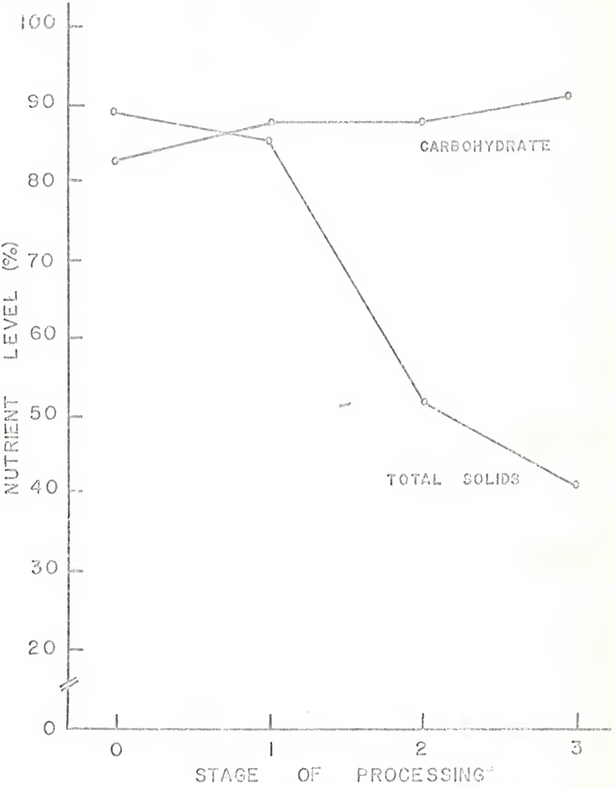

Fig. 5. Effect of processing on the level of carbohydrate and total solids of the mature corn kernel. (* As in Fig. 6)

kernel, these structures contain from 75 to 85% of the minerals present (8, 20). The removal of most of these mineral-rich structures during the milling process was a major factor accounting for the low levels of ash in the final products. It can be observed from Table 5 and Fig. 6 that 64.7% by weight of the mineral elements present in corn kernel was lost to milling operations. Processes of fermentation increased this loss to 96.3%. Although the observed changes cannot be fully explained some light is shed in this direction by the work of Greaves and Hirst (42). These workers observed that during the storage of flour and more slowly in unmilled grain, phytin, a calcium-magnesium salt of inositol phosphoric acid was acted upon by the enzyme phytase with the liberation of water-soluble phosphorus compounds. If the possibilities of these reactions occurring during the fermentation process were assumed, then subsequent leaching of these soluble products into the water used in boiling the dough would reasonably account for the increased losses. The apparent increase in the ash level in kenkey could be due to the addition of common salt during processing. It is also possible for the percentage of total mineral matter in the kenkey to increase because of the loss of other constituents.

Protein level followed a decreasing trend with processing as shown in Table 5 and in Fig. 6. The 12.8% loss of crude protein during milling was probably due to partial removal of germ and hull with some endosperm, particularly aleurone cells. It has been reported (52) that during fermentation proteolytic enzymes in the grain and organisms associated with grain will hydrolyse the proteins into polypetides and finally into amino acids. Loss of nitrogenous compounds would be reflected in greater decreases of protein level. The protein level decreased by 44.0% in the final product. This

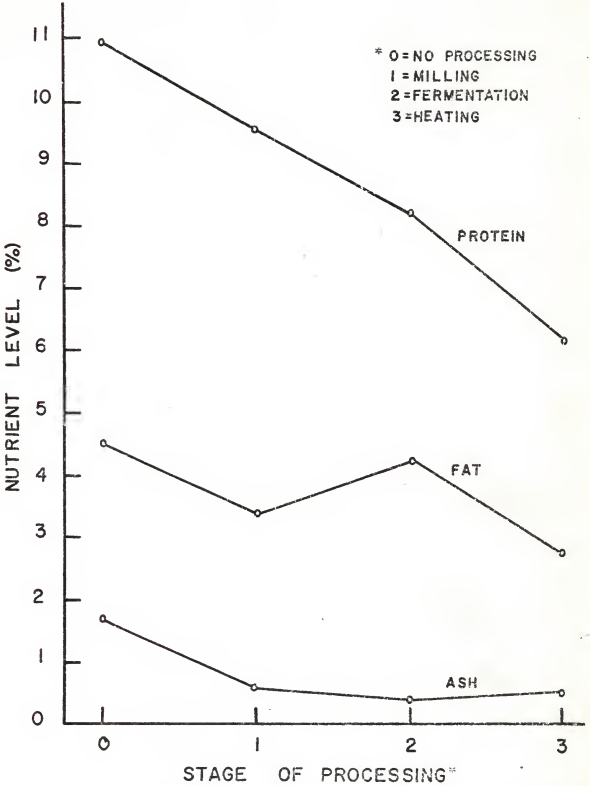

Fig. 6. Effect of processing on the levels of protein, fat and ash of the mature corn kernel.

loss was probably due to leaching of soluble amino acids and proteins into the same water used for boiling kenkey. The high boiling temperatures would denature some of the proteins.

Since the germ of the mature corn kernel contains 83% by weight of all fat present in the entire kernel (20), removal of the germ during milling resulted in the observed decreased value. Fermentative changes occurring in corn fat or oils might be either oxidative, resulting in flavors and odors akin to rancidity, or hydrolytic, resulting in the production of free fatty acids. From studies on the storage of grain oils and of milled products, particularly milled whole grain products, Zeleny (86) reported that fats in grain were readily broken down by lipases into free fatty acids and glycerol particularly when the temperature and moisture content were high. Such changes might decrease the fat content either through loss of volatile fatty acids or the reconstitution of fatty acids and glycerol with other compounds to form non-fatty products. It is known, however, that during the enzymatic conversion of glucose or other carbohydrate into alcohol and carbon dioxide, certain intermediary compounds are formed which can result in the formation of fatty acids, fats and steroids according to the path of the reactions as follows (19, 26, 73):

Polysaccharide Glucose 6-phosphate

Pyruvate

Acetyl coA CO_2

Fatty acids, steroids, etc.

These reactions could probably increase the fat content of a fermenting dough; but the recorded decrease (6.6%) would indicate that the concentration of fat so synthesized was not enough to offset the previous loss resulting

from milling. As with other nutrients, the large quantities of water used to boil kenkey probably caused the major loss of fat through leaching.

Carbohydrates.

The carbohydrate content would be expected to decrease as a result of the fermentation reactions, however; because it was determined by difference, loss of other nutrients led to increasing values, as shown in Tables 4, 5, and in Fig. 6.

Energy value.

In comparison with other nutrients, the changes observed in energy value during the processing of mature corn kernel into kenkey were relatively smaller. Data for these observations are shown in Tables 4, 5, and by Fig. 7. The energy content of food is conventionally estimated either by 1) direct measure of heat evolved during combustion of the food in a calorimeter or 2) from chemical analysis for protein, carbohydrate and fat and by multiplying the respective values by the factors of 4, 4, and 9 cals. per gram (3, 67). The limitations of these latter approximations have been amplified by Rice (67): "Although they are adequate for most purposes, they greatly oversimplify the situation with respect to the actual amount of energy available for use by man or animals. For more exact values, the degree of availability of nutrients need be determined by biological tests which measure the disappearance of nutrients from the digestive tract, the intake of oxygen and the output of carbon dioxide, along with the heat produced, the work done and -- ideally -- changes in tissue composition. This is obviously rather slow, exacting work and it requires complicated and costly equipment."

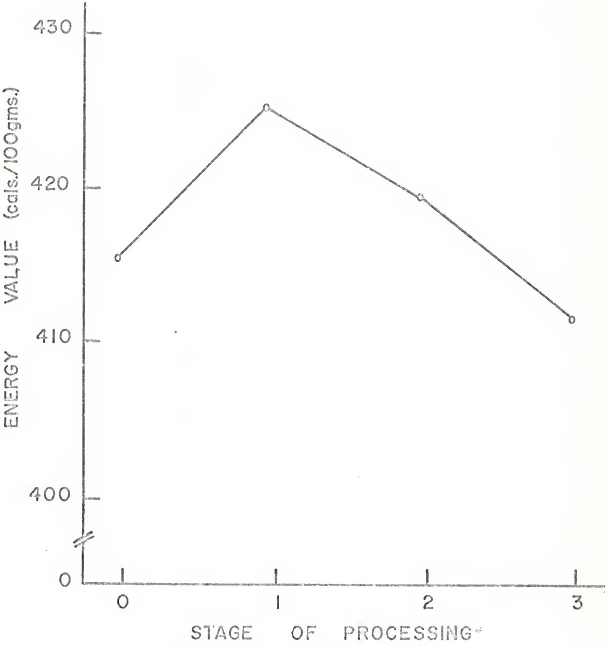

Fig. 7. Effect of processing on the energy value of the mature corn kernel. (* As in Fig. 6)

Effect of Various Fermentation Periods on the Weight, pH and Non-reducing Sugars on Corn Meal Dough and on the Organoleptic Properties of Kenkey

Changes in Weight.

As fermentation progressed increasing loss of weight was recorded as shown in Table 6 and in Fig. 8. Weight losses of fermenting dough may be considered in three categories: 1) evaporation of water present as moisture in the dough, 2) loss of gases such as carbon dioxide arising from the breakdown of carbohydrates; and 3) evaporation of volatile substances such as water, alcohol, organic acids, and the like which are produced from fermentation reactions.

Table 6. Effect of various fermentation periods on the pH, non-reducing sugars and gross weight of corn meal dough.

Fermentation time (hrs.)	pH	Non-reducing sugars*	% Weight loss+
0	6.1	168	0
12	6.0	161	2.7
24	5.7	153	3.8
36	5.2	128	5.2
48	4.3	120	6.4
60	4.8	117	7.8
72	5.0	106	8.9

* Expressed as mg. sucrose per 10 gm. corn meal on dry basis.

\+ Expressed on wet basis.

Changes in dough pH.

The curve in Fig. 9 charts the course of pH during a 72 hour fermentation

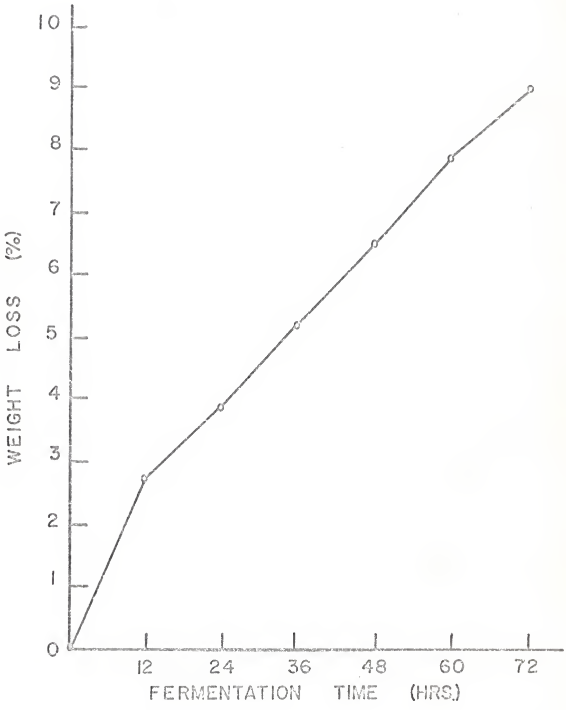

Fig. 8. Effect of various fermentation periods on the weight of corn meal dough.

period of dough. Recorded data are reported in Table 6. It can be observed that the pH decreased from an initial value of 6.1 to 4.3 after 48 hours and then increased to 5.0, although this further increase was less than the initial decrease. Organic acids produced from the fermentation of carbohydrates, fats and proteins may logically be expected to lower the pH since they show some degree of ionization. Evaporation of some volatile organic acids or reconstitution of these acids would increase the pH as observed after the 48th hour.

Changes in Non-reducing Sugars.

The effect of fermentation time on the concentration of non-reducing sugars in fermenting corn meal dough is shown in Table 6 and in Fig. 10. Non-reducing sugars dropped from an initial value of 168 mg. during the 72 hour fermentation period.

Since changes in weight, pH, and non-reducing sugars of fermenting grain are enzymatic in nature (12) these factors may be used as indices of the rate of fermentation in kenkey processing.

Organoleptic Properties.

Both under-fermentation and over-fermentation appeared to have unfavorable effects on the eating qualities of kenkey. Average organoleptic scores are represented in Table 7 and in Fig. 11. Total score increased up to the 36th hour of fermentation and then followed a decreasing trend. With increasing fermentation periods flavor became pronounced with an alcoholic and vinegary taste. The lowest pH, 4.3, was recorded on the 48th hour of fermentation and the product produced irritating sensations in the mouth, particularly in the cheeks, resembling the taste of vinegar. Prolonged

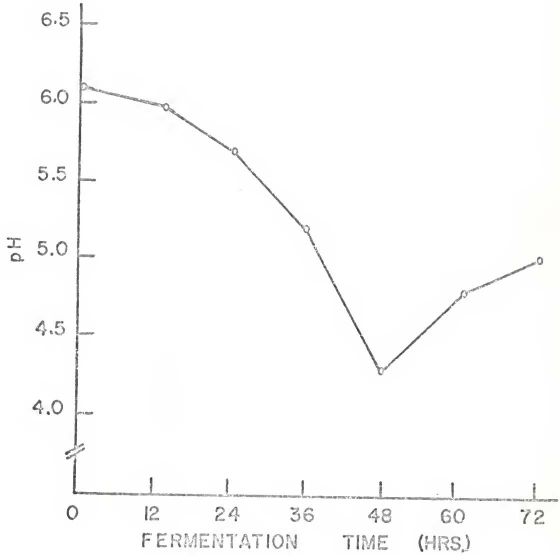

Fig. 9. Effect of various fermentation periods on the pH of corn meal dough.

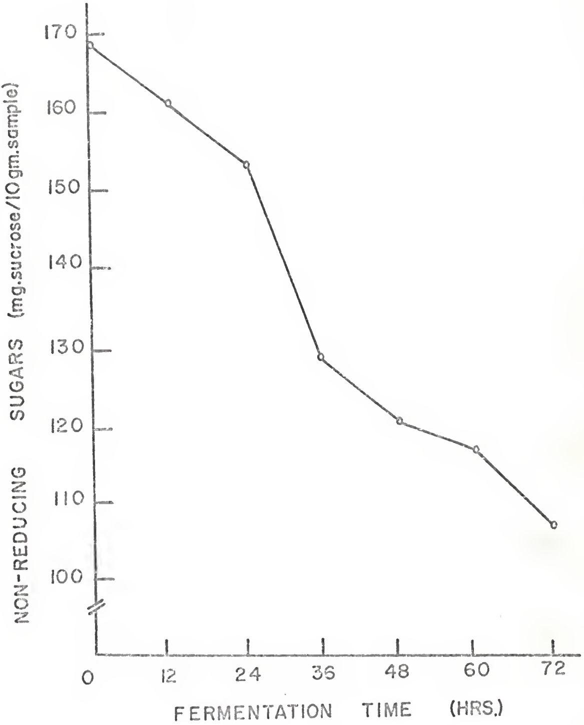

Fig. 10. Effect of various fermentation periods on the concentration of non-reducing sugars of corn meal dough.

Table 7. Average organoleptic scores for kenkey.

Factors	Points possible		SAMPLES, POINTS SCORED Fermentation time in hours					
	Gross	Distribution	12	24	36	48	60	72
General appearance	25							
Color		10	10	10	8	8	8	6
Shape		5	4	4	4	4	4	4
Size		10	10	10	10	10	8	8
Internal features	35							
Grain		15	12	12	12	12	12	12
Texture		20	16	16	16	16	16	16
Flavor	40							
Taste		20	8	12	16	12	12	4
Odor		20	8	8	12	12	4	4
Total	100	100	68	72	78	74	64	54

fermentation (60 to 72 hours) produced off flavors which masked the typical corn flavor. Resulting products could still be eaten but without much enthusiasm. Irritation in the cheeks was very pronounced and the product was considered undesirable. Products of under-fermentation (up to 24 hours) lacked the kenkey flavor. It might be suggested from these results that optimum fermentation time for the dough at 85°F. and 80% relative humidity was 36 hours. Also it is from the fermentation reaction that kenkey acquires its associated flavor.

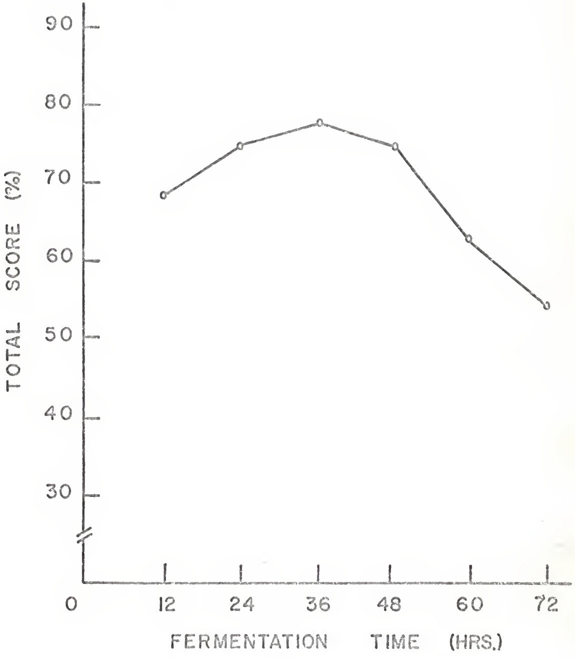

Fig. 11. Effect of various fermentation periods on the organoleptic scores for kenkey.

Effect of Kenkey on the Growth Rate of Sprague-Dawley Rats

The over-all effect of kenkey on growth rates of rats, as shown in Table 8 and in Fig. 12 indicated that the product could not support growth.

Table 8. Effect of kenkey on the rate of growth of Sprague-Dawley rats.

Time (in days)	Cumulative weight gain (in gms.)	
	Control diet	Kenkey
0	0	0
1	2	-11
3	4	-11
6	26	-23
8	38	-26
10	50	-31
13	61	-33
14	66	-37

The physiological function of food may be divided into three categories: (i) to supply energy, (ii) to build and maintain the cells and tissues, and (iii) to regulate body processes (85). These needs are satisfied by substances in nutrients which are found in the food man eats. The nutrients themselves have been subdivided into six general classes: carbohydrates, lipids (fats), proteins, minerals, vitamins, and water. The value of certain of these substances for the nutrition of an animal can be determined by feeding the animal a diet in which the substance to be tested is present only in limited amounts or absent altogether. The animal will respond with growth

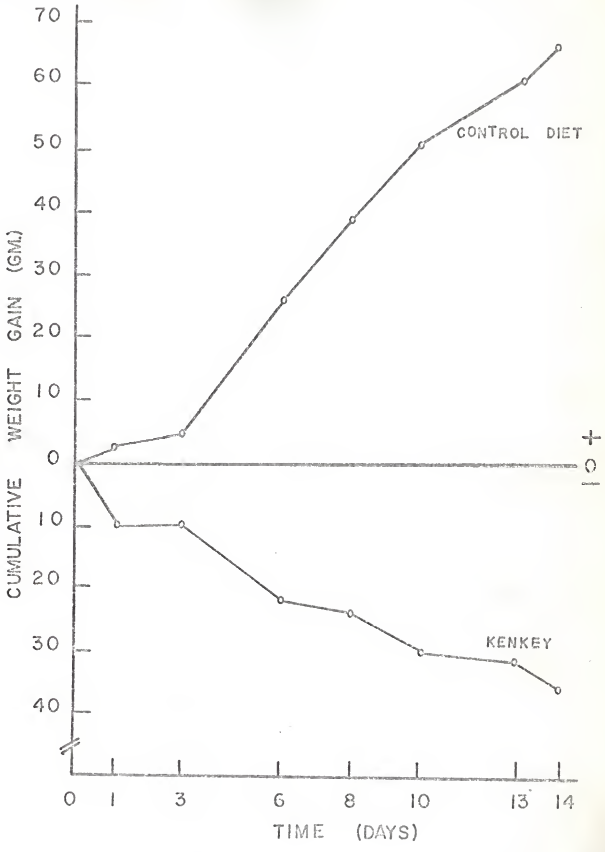

Fig. 12. Effect of kenkey on the growth curve of Sprague-Dawley rats.

failure or possibly with specific deficiency symptoms. Corn and corn diets are generally known to have low biological and nutritive values (22, 32, 35, 47, 63, 70) and even though kenkey is generally eaten with a stew, fish or meat with sauce, gravy or a variety of soup preparations intended to offset the deficiencies of nutrients the present data on the growth of rats are still significant in that they indicate additional nutritional supplements are needed to ensure growth. Such nutritional supplementation could be made either through processing or as an addition to the diet when served at table.

CONCLUSIONS

An investigation of some of the more important methods of processing kenkey and their influence on the quality of the product has been conducted. The processes of milling, fermentation and heat treatment tended to reduce the nutritive value of the product, with greatest losses resulting from heat treatment. The typical flavor of kenkey was a result of fermentation reactions and was adversely affected by both under- and over-fermentation. Optimum fermentation time, with respect to organoleptic judging was found to be 36 hours. Improper mixing and imbalances of water during dough make-up produced poor quality products. The use of aluminum foil and plastic sausage casings instead of traditional corn husks and plantain leaves as wrapping materials and the addition of imitation corn flavor aesthetically improved the acceptability of the product. The development of a score card for use in the organoleptic judging of kenkey could be improved to standardize quality factors, besides it would serve as a basis for comparing this product with other foods. The results of animal feeding trials showed that the nutritional value of kenkey was not enough to support growth even when the

product was served ad. lib. By reference to the control diet, the studies did indicate the need for adequate nutrient supplementation for healthy growth. To embark on such a nutritional enrichment program, further studies on the nutritional properties of kenkey and the techniques of processing with due respect to consumer preferences, food habits and their socioeconomic needs are required. If the present studies should stimulate interest in the undeveloped science and technology of kenkey in an effort to improve its nutritional qualities, the author's objectives would have been worthwhile.

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STUDIES ON KENKEY -- A FOOD PRODUCT
MADE FROM CORN IN GHANA

by

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B.Sc. (Agric.), University of Ghana, 1964

AN ABSTRACT OF A MASTER'S THESIS

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MASTER OF SCIENCE

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1967

There is a growing need in the world today for the provision of food, in quality and in quantity for the health and normal development of man. This need calls attention to the necessity for re-evaluation of existing methods of food processing and technology, particularly in developing countries. To this end, the effects of some of the more important factors on the quality of kenkey -- a food produced from corn in Ghana -- have been investigated.

The results of the studies indicated that the process of milling, fermentation, and boiling at a high temperature involved in making kenkey lead to a reduction of the nutritive value of the product. Nutrient losses due to the milling of the corn could be accounted for by the fact that in the normal processing of kenkey a large proportion of the hull, tip cap and germ of the mature corn kernel is discarded. In addition to this, some material losses occur as dust during grinding and sifting. Fermentative losses result principally from biochemical changes involving the decomposition of starch and sugars to carbon dioxide, water and volatile compounds. The process of fermentation was found to be an essential phase in kenkey making, because on it depend the entire flavor characteristics of the product. Under-fermentation was as undesirable as over-fermentation. Nutrient losses were accentuated, generally, during the conversion of the fermented dough into the final product, which involved boiling in excess water for approximately two hours at between 200 and 210°F. Soluble nutrients could be leached into the cooking water which was subsequently discarded. The use of artificial corn flavor to enhance the flavor of the product, and of aluminum foil or plastic sausage casings instead of corn husks or plantain leaves as packaging materials could be significant contributions to the

kenkey industry. A score card was developed for use in the organoleptic judging of kenkey. A feeding trial using white Sprague-Dawley rats indicated that kenkey alone could not support growth.